ORDER

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

6950.25

10/31/85

SUBJ: USE OF ELECTRICAL POWER CONDITIONING DEVICES AT FAA FACILITIES

1. PURPOSE. This order provides selection guidance for electrical power conditioning devices and clarifies the conditions for which their use is authorized at Federal Aviation Administration (FAA) facilities in the National Airspace System (NAS) in accordance with Orders 6030.20D and 6950.2B, Electrical Power Policy and Electric Power Policy Implementation At National Airspace System Facilities.

2. DISTRIBUTION. This order is distributed to branch level in the Program Engineering and Maintenance Service, Air Traffic Operations Service, Air Traffic Plans and Requirements Service, in the Office of Flight Operations, and in the Office of Airport Standards in Washington headquarters; to branch level in regional Air Traffic and Airway Facilities divisions; and to all Airway Facilities sectors, sector field offices, sector field units, and sector field office units.

3. BACKGROUND. Orders 6030.20D and 6950.2B establish policy and guidance for the quality of electrical power furnished to NAS facilities. As power demands increased, in what were once isolated and unpopulated areas, the quality of commercially supplied power has been altered at some of the previously problem-free facilities. Many remote and unmanned facilities are now exposed to power interruptions and line disturbances. In addition, the use of state-of-the-art technology and changes in FAA maintenance philosophy have increased the need for precise quality power to provide the required service reliability at unmanned facilities. As mandated by administrative policies, the agency must also be conscious of energy conservation practices and cost-effective solutions. In light of these restrictions, power conditioning devices should only be employed at facilities where required and selected by individual needs and site-specific deficiencies.

4. APPLICATION.

a. This order is to be applied in concert with Orders 6030.20D and 6950.2B to provide the optimum type and quality of electrical power necessary to ensure the degree of overall facility availability commensurate with its assigned mission.

b. The guidance provided by this order applies to all proposed, authorized, and commissioned FAA facilities in the NAS.

5. CRITERIA.

a. After all efforts have been made to ensure that a facility is within

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current standards, the quality of the primary source of power can be considered insufficient to provide the service and reliability required by the facility if any of the conditions below exist.

(1) Power line disturbances of a nature that may create an unsafe condition to air traffic.

(2) Power line disturbances are frequent and are of a nature that results in damage to equipment components.

(3) The number of facility outages (interruptions to services) are excessive and considered unacceptable by the user.

(4) Power line disturbances result in outages requiring manual intervention to restore service at unmanned facilities.

b. If it is determined that the quality of the primary source of power is insufficient and not practical to correct and modification of the existing FAA equipment to improve its performance is not feasible, a power conditioning device may be used to upgrade the incoming power to an acceptable level.

c. Power conditioning devices shall only provide service to equipment that is required to be operational for the safety of air traffic, and it has been determined that its operation is adversely affected by power line disturbances as discussed in paragraph 5a.

6. DEVICE SELECTION AND GUIDANCE.

a. Prior to the selection of a power conditioning device, initial steps should be performed to ensure that the facility meets or has been upgraded to current standards, the criteria specified in paragraph 5b has been satisfied, and the types of power line disturbances causing the problems have been identified. Definitions of power disturbances are contained in Appendix 1, Definitions And Terms, and a list of recommended initial steps are in Appendix 2, Power Problem Corrective Matrix.

b. The power problem corrective matrix and instructions which references power conditioning devices to types of power line problems are provided in appendix 2. The matrix should be used to identify all possible solutions to a facility's problems. Final selection is to be based on required maintenance interval, cost-effectiveness, and impact to facility operation to install. The maintenance interval of the power conditioning device must not be less than that of the existing equipment nor be less than the limits established by the maintenance philosophy of the time. Average life-cycle costs (simple costs), maintenance requirements, and operating cost comparison charts are contained in Appendix 3, Comparison Charts, for typical systems of various sizes.

c. Facility wiring, electric service capacity, and the standby power system must be compatible with the power conditioning device. If conflicts exist, projects will have to be budgeted and authorized to modernize or replace undersized power distribution systems and engine generators to accommodate the proper power conditioning device. Wherever feasible, facility standards and standard installation drawings shall be used to the most practical extent.

d. Systems, subsystems, and equipment under configuration management shall not be modified until an approved configuration control decision is issued following a NAS change proposal request. Specific systems, subsystems, and equipment under configuration control are listed in NAS-MD-001, National Airspace System Configuration Management Document.

7. RESPONSIBILITIES.

a. Regions will periodically review facility service performance and the quality of electrical power to ensure that the overall facility availability is within the conditions defined by Orders 6030.20D and 6950.2B.

b. The appropriate Washington headquarters program office shall provide procurement guidance and installation standards for the major power conditioning devices (uninterruptible power supplies, motor generators, etc.). Equipment shall be installed in accordance with standards current at the time.

8. IMPLEMENTATION. All commissioned facilities shall be provided with power that is within the prescribed limits established by the facility standards and instructions and Orders 6030.20D and 6950.2B. This order shall be applied as a supplement when facility service requirements are upgraded to the level where precise quality power is required or when the quality of the commercial power source deteriorates to the level where facility service is below the minimum requirements.

a. Power conditioning devices shall only be considered after it has been determined that the facility is up to current standards and the nature of the power line disturbances affecting the equipment identified. Power line disturbance measurements to be used in the device selection procedure should not be made until all site deficiencies have been corrected.

b. The power problem corrective matrix contained in appendix 2 will be used with the life-cycle cost estimates described in appendix 3 to arrive at the most cost-effective solution. When considering life-cycle costs, particular attention should be given to maintenance requirements and operational costs. Appendix 3, figures 2 and 3, provide relative cost data in these areas.

c. Transition to upgraded configurations will be accomplished at the earliest possible time in accordance with normal budgetary procedures and approvals.

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APPENDIX 1. DEFINITIONS AND TERMS

1. GENERAL. To ensure uniform interpretation, the following definitions and terms shall be used in the discussion of power-related problems.

2. DEFINITIONS.

a. Brownout. Brownouts are continuous cycle-to-cycle decreases in the power line voltage on any combination from one to all phases of a single-phase or multiphase system. The voltage reduction can be constant or slowly varying. Brownouts are usually caused by heavily loaded power networks/transmission lines or planned reduction by the utility company. Brownouts are normally of long durations, i.e., long-term sags.

b. Flicker. A flicker is a zero or near zero voltage condition lasting up to 0.5 second on any one or all of the three phases. Flickers can be considered a special case of a severe voltage sag or a short momentary interruption. Flickers can occur in multiple successions.

c. Lightning Induced Transients. Lightning induced transients are high-voltage transients induced on any or all of the power lines, transmission lines, building steel, or other types of metal material in the vicinity of currents or an electromagnetic field created by an atmospheric discharge. The induced voltage can vary in amplitude from 300 to 6,000 volts. The transients are generally of short duration, ranging from 10 nanoseconds to 0.05 second.

d. Momentary Interruption. A momentary interruption is a zero or near zero voltage condition lasting up to 1 second on any one or all of the three phases. On a multiphase system, the loss of voltage may be of equal amplitude or vary with each phase. Interruptions of a duration less that 0.5 seconds are considered to be flickers.

e. Noise. Noise, sometimes referred to as spikes, impulses or transients, is an unwanted disturbance superimposed on the voltage waveform. Noise can be periodic, nonperiodic, continuous, or random. Noise is normally classified in two modes of occurrences.

(1) Common-Mode Noise. Noise that can occur between ground and current-carrying conductors.

(2) Transverse-Mode Noise. Noise that occurs between the two current carrying conductors.

f. Power Failure. A power failure is a zero voltage condition lasting for longer than 1.0 second. The failure can occur on any combination from one to all phases of a single-phase or multiphase system.

g. Sags. Sags are cycle-to-cycle decreases in the power line rms voltage and are normally of short duration. Long-term sags (1.0 second or longer) are brownouts and deep sags (25 percent or larger reduction) may be considered as flickers.

h. Surges. Surges are cycle-to-cycle increases in the power line voltage and are normally of short duration.

3. CORRECTIVE DEVICE TERMS.

a. Power enhancement devices improve the raw utility waveform in some manner (by clipping, filtering, attempting to prevent level fluctuation, etc.) and apply the results to the load. Some of the common devices are listed below.

(1) Surge Suppressors. These devices will clip voltage surges or noise spikes at a specified voltage and speed (typically less than 0.5 nanoseconds). Surge suppressors are primarily used to prevent equipment damage from short duration transients. Long-term surges will exceed the device's energy rating thus causing failure. Typical devices employ metal-oxide varistors (MOV), gas discharge tubes, or solid-state clipping circuitry. It should be understood that surge suppressors will have no effect on transients until the transients exceed the threshold voltage of the surge suppressors.

(2) Isolators.

(a) Isolation Transformers. These devices will eliminate common-mode noise (up to approximately 120 decibels) when properly shielded, but will have little effect on transverse noise reduction. The isolation transformer offers no line regulating ability.

(b) Ultra-Isolators. These devices use transformers with additional shielding and winding separation to improve transverse-mode noise rejection. They will typically reduce common-mode noise by 140 decibels and transverse noise by 60 decibels.

(3) Regulators. Most regulators are ferroresonant type (shielded and unshielded) or the tap-switching type. Both types provide reasonable steady long-term voltage levels, but inherently allow short-term disturbances to pass to the load. Typically, regulators alone provide no isolation, little transient protection, and cannot correct voltage waveform distortion. However, some regulators are available with shielded isolation transformers in the front end (power conditioners).

(a) Tap-Switching Type (With Isolation). Most units provide good noise suppression (approximately 20 decibels) and voltage regulation. The response time of these units is typically one cycle for 100 percent correction, which is slightly faster than the ferroresonant type. Most systems are designed so that switching occurs near the zero crossing to eliminate noise at the output.

(b) Ferroresonant Type (Constant Voltage Transformer). These devices, when shielded, will eliminate transverse and common-mode noise. Response times of 1 1/2 cycles are typical. However, these regulators may introduce noise on the input voltage line which could affect other equipment.

b. Power synthesis devices utilize the utility power only as an energy source from which to generate a new, completely isolated waveform.

(1) Static Magnetic Synthesizer. This device operates on the fundamental properties of electromagnetics. The device consists of magnetic and capacitive elements and produces a power waveform of the identical frequency as the original. Magnetic synthesizers provide noise immunity and voltage regulation. Most available devices will offer 1 cycle ride-through (16.7 milliseconds) and automatic restart upon restoration of power. In addition, the output will ramp-up and down rather than step during return and loss of power.

(2) Dynamic Power Synthesis (Motor Generator). These devices consist of an induction or synchronous motor mechanically coupled to an alternating current generator. The motor is driven by the power line either at fixed or synchronous speed, and the generator produces a new waveform of the identical frequency. The synchronous motor will operate at line frequency while the induction motor's speed will vary with load. In addition, the synchronous motor generator offers regulation and isolation from both modes of noise. However, without a fly wheel or battery backup power, the motor generator will only provide 0.5 seconds of ride-through (at full load) before it disconnects from the load.

(3) Uninterruptible Power Supplies (UPS). These devices employ a means for charging a bank of batteries, as a backup for the commercial power. They may employ either an inverter or a motor driven generator for power output.

(a) Static UPS. The static UPS uses static electronic synthesizers (inverters) to convert direct current to alternating current. A rectifier and a bank of batteries are used to supply the direct current to the inverter. The inverter can either provide output constantly or when the input voltage is out of tolerance through the use of a solid-state switch or control of the phase angle of the synthesized voltage. Large inductive loads, such as motors, are not recommended for the static UPS.

(b) Rotary UPS. These devices normally consist of a synchronous or asynchronous motor, synchronous or asynchronous generator, a direct current motor/generator, and a bank of batteries. During normal operation, the alternating current motor drives the alternating current generator and the direct current motor/generator which provides charge voltage for the batteries. Upon loss of primary input power, the direct current motor/generator will act as a motor, through a phase shift in the field winding, and drive the alternating current generator. The rotary UPS will eliminate noise, regulate voltage, and provide limited standby power.

APPENDIX 2. POWER PROBLEM CORRECTIVE MATRIX

1. GENERAL. This appendix contains the Power Problem Corrective Matrix, it's instructions and the initial and final steps that should be performed in the selection of a cost-effective power conditioning device. The life-cycle costing data provided by the matrix and appendix 3 is based on simple cost comparison estimates available at the time of this publication. The relative cost figures are provided for comparison purposes only and should not be used for actual project cost estimates.

2. INITIAL STEPS.

a. Survey facility's plant and electronic systems for deviations from current agency standards.

b. Where feasible, resolve related equipment design defects and malfunctions through approved procedures.

c. Adjust operational procedures if possible, e.g., use engine generator power during storm activity.

d. Use measuring devices, voltage analyzers, to determine whether power problem actually exists and if so, which power line disturbances are causing problems.

e. Discuss correction of the problems with local utility company.

f. Determine whether the minimum facility operational requirements warrant upgrading the power.

g. Identify the critical load.

3. USE OF POWER PROBLEM CORRECTIVE MATRIX. The matrix is presented in figure 1. In some situations, more than one solution or a combination of devices may be indicated by the matrix. The instructions presented below are provided to assist in the determination of the most cost-effective device(s) to resolve the problem.

a. Based on minimum operational requirements, first determine all possible solutions. The solution can consist of more than one device or different devices for portions of the critical load.

(1) Match devices to problems as closely as possible.

(2) Use power synthesis devices only where necessary, e.g., where large voltage sags occur, where an extremely fast response time is required, or where no other solution exists.

(3) Use uninterruptible power supplies if operational requirements call for continuous operation or if frequent momentary interruptions occur.

FIGURE 1. POWER PROBLEM CORRECTIVE MATRIX

DEVICES / POWER PROBLEMS	SURGE (SPIKE) SUPPRESSOR	ULTRA ISOLATOR	REGULATOR (W/ISOLATION)	CONSTANT VOLTAGE TRANSFORMER	MAGNETIC SYNTHESIZER	MOTOR GENERATOR	STATIC UPS	ROTARY UPS
MOMENTARY INTERRUPTIONS							▨	▨
SAG			▨	▨	▨	▨	▨	▨
SURGE			▨	▨	▨	▨	▨	▨
NOISE		▨	▨		▨	▨	▨	▨
LIGHTNING	▨							
BROWNOUT			▨	▨	▨	▨	▨	▨
POWER FAILURE							▨	▨
FLICKER						▨	▨	▨
LOSS OF ONE PHASE						▨	▨	▨

TYPICAL OPERATING PARAMETERS OF DEVICES

INPUT VOLTAGE RANGE	UP TO 6kV	-140dB CM -60dB TM (SEE NOTE 1)	-20% to 10%	-25% to 10%	30%	30%	10%	-40% to 20%
REGULATION	N/A	N/A	3%	1%	3%	1%	1%	1%
EFFICIENCY	N/A	96%	93%	90%	90%	90%	86%	88%
RESPONSE TIME	5ns	N/A	1 CYCLE	1.5 CYCLE	3 CYCLES	1 CYCLE	1 CYCLE	1 CYCLE
AVAILABLE LOAD RATINGS	SEE NOTE 2	.125 to 130kVA	0.5 to 100kVA	30VA to 15kVA	10kVA to 150kVA	12.5kVA to 500kVA	1kVA to 600kVA	10kVA to 500kVA
LIFE-CYCLE COSTING (YR) (SEE NOTE 3)	$90	$7,196	$8,815	SEE NOTE 4	$12,875	$15,574	$27,212	$28,813

KEY:

▨ - DEVICES ARE EFFECTIVE

☐ - DEVICES ARE NOT EFFECTIVE

NOTES:
1. ATTENUATION OF COMMON MODE AND TRANSVERSE NOISE.
2. SURGE POWER RATING WILL VARY DEPENDING ON CLAMPING VOLTAGE OF THE SURGE SUPPRESSOR AND THE DURATION OF THE SURGE.
3. COSTS ARE BASED ON DEVICES RATED AT 100kVA OUTPUT.
4. NOT AVAILABLE IN THIS LOAD RANGE

b. Compare the facility's equipment loading profile to the conditioning device's output characteristics, i.e., an inductive load will lower a static inverter's kilowatt (kW) rating, and in some cases the bypass operation of a motor generator following a power failure will result in an out-of-phase transfer of the load which can cause circuit breakers to operate.

c. An analysis of the facility's wire sizes and wire condition should be performed to determine installation problems. The service entrance switch rating and fuse size must be included in the analysis. If an UPS is selected, determine if the existing facility's engine generator is capable of supporting the additional load. Motor generators are not to be operated on standby power.

d. If more than one solution exists, make final selection based on life-cycle cost, operating cost, maintenance requirements, and which device will least impact facility operation and configuration to install.

e. Contact the local utility company when installing large devices (rated output approximately equal to total facility load) to ensure service can support the equipment. Particular attention should be given to inrush currents required to power-up the device, especially when using rotating or inductive equipment such as motor generators and rotary UPS.

f. Proceed with budgetary, programming, and other administrative activities to accomplish the corrective actions.

APPENDIX 3. COMPARISON CHARTS

TABLE 1. POWER PROBLEM CORRECTIVE MATRIX
SIMPLE COST COMPARISON CHART
SINGLE-PHASE

5000 VA EQUIPMENT SIZE

	SURGE (SPIKE) SUPPRESSOR	ULTRA-ISOLATOR	REGULATOR (W/ISOLATION)	CONSTANT VOLTAGE TRANSFORMER	MAGNETIC SYNTHESIZER	MOTOR GENERATOR	STATIC UPS	ROTARY UPS
EQUIPMENT COST(EC)	$500	$400	$2,120	$2,250	N/A	N/A	$10,000	N/A
INSTALLATION COST (IC)	$500	$500	$5,000	$2,500	N/A	N/A	$20,000	N/A
OPERATING COSTS/YR (OC)	$0	$184	$264	$389	N/A	N/A	$618	N/A
MAINTENANCE COST/YR (MC)	$0	$0	$250	$0	N/A	N/A	$3,000	N/A
SPARE PARTS (SP)	$0	$0	$0	$0	N/A	N/A	$1,500	N/A
TRAINING COSTS (TC)	$0	$0	$1,500	$0	N/A	N/A	$15,000	N/A
SERVICE LIFE YRS (SL)	20	20	20	20	N/A	N/A	20	N/A
MTBF	---	---	22,000	50,000	N/A	N/A	60,000	N/A
LIFE-CYCLE COSTS	$50	$229	$945	$627	N/A	N/A	$5,943	N/A

LIFE-CYCLE COSTS EQUALS ((EC+IC+SP+TC)/SL)+OC+MC $ PER YEAR

ENERGY COSTS - $0.1/kWh

IF DEVICE IS LOCATED IN HVAC AREA MULTIPLY OPERATING COST FACTOR BY 1.33%

TABLE 2. POWER PROBLEM CORRECTIVE MATRIX
SIMPLE COST COMPARISON CHART
THREE-PHASE

12,500 VA EQUIPMENT SIZE

	SURGE (SPIKE) SUPPRESSOR	ULTRA-ISOLATOR	REGULATOR (W/ISOLATION)	CONSTANT VOLTAGE TRANSFORMER	MAGNETIC SYNTHESIZER	MOTOR GENERATOR	STATIC UPS	ROTARY UPS
EQUIPMENT COST(EC)	$500	$4,200	$7,500	$6,300	$9,000	$25,100	$22,000	$30,200
INSTALLATION COST (IC)	$500	$2,500	$5,000	$2,500	$25,000	$50,000	$50,000	$50,000
OPERATING COSTS/YR (OC)	$0	$461	$659	$973	$973	$973	$1,546	$1,195
MAINTENANCE COST/YR (MC)	$0	$250	$500	$250	$500	$1,500	$3,000	$3,000
SPARE PARTS (SP)	$0	$0	$1,125	$0	$1,350	$3,765	$3,300	$4,530
TRAINING COSTS (TC)	$0	$0	$1,500	$0	$1,500	$4,000	$15,000	$6,000
SERVICE LIFE YRS (SL)	20	20	20	20	20	20	20	20
MTBF	---	---	22,000	50,000	50,000	100,000	60,000	100,000
LIFE-CYCLE COSTS	$50	$1,046	$1,916	$1,663	$3,316	$6,617	$9,061	$8,731

LIFE-CYCLE COSTS EQUALS ((EC+IC+SP+TC)/SL)+OC+MC $ PER YEAR

ENERGY COSTS - $0.1/kWh

IF DEVICE IS LOCATED IN HVAC AREA MULTIPLY OPERATING COST FACTOR BY 1.33%

TABLE 3. POWER PROBLEM CORRECTIVE MATRIX
SIMPLE COST COMPARISON CHART
THREE-PHASE

50,000 VA EQUIPMENT SIZE

	SURGE (SPIKE) SUPPRESSOR	ULTRA-ISOLATOR	REGULATOR (W/ISOLATION)	CONSTANT VOLTAGE TRANSFORMER	MAGNETIC SYNTHESIZER	MOTOR GENERATOR	STATIC UPS	ROTARY UPS
EQUIPMENT COST(EC)	$500	$10,000	$15,000	N/A	$23,000	$32,000	$77,000	$51,800
INSTALLATION COST (IC)	$500	$50,000	$50,000	N/A	$50,000	$70,000	$100,000	$100,000
OPERATING COSTS/YR (OC)	$0	$1,844	$2,637	N/A	$3,893	$3,893	$6,184	$4,778
MAINTENANCE COST/YR (MC)	$0	$250	$500	N/A	$500	$1,500	$3,000	$3,000
SPARE PARTS (SP)	$0	$0	$2,250	N/A	$3,450	$4,800	$11,550	$7,770
TRAINING COSTS (TC)	$0	$0	$1,500	N/A	$1,500	$4,000	$15,000	$6,000
SERVICE LIFE YRS (SL)	20	20	20	N/A	20	20	20	20
MTBF	---	---	22,000	N/A	50,000	100,000	60,000	100,000
LIFE-CYCLE COSTS	$50	$5,094	$6,575	N/A	$8,291	$10,933	$19,361	$16,057

LIFE-CYCLE COST EQUALS ((EC+IC+SP+TC)/SL)+OC+MC ($ PER YEAR)

ENERGY COSTS - $0.1/kWh

IF DEVICE IS LOCATED IN HVAC AREA MULTIPLY OPERATING COST FACTOR BY 1.33%

**TABLE 4. POWER PROBLEM CORRECTIVE MATRIX
SIMPLE COST COMPARISON CHART
THREE-PHASE**

75,000 VA EQUIPMENT SIZE

	SURGE (SPIKE) SUPPRESSOR	ULTRA-ISOLATOR	REGULATOR (W/ISOLATION)	CONSTANT VOLTAGE TRANSFORMER	MAGNETIC SYNTHESIZER	MOTOR GENERATOR	STATIC UPS	ROTARY UPS
EQUIPMENT COST (EC)	$500	$12,000	$19,000	N/A	$30,000	$39,000	$97,000	$88,600
INSTALLATION COST (IC)	$500	$50,000	$50,000	N/A	$50,000	$70,000	$100,000	$100,000
OPERATING COSTS/YR (OC)	$0	$2,766	$3,956	N/A	$5,840	$5,840	$9,275	$7,167
MAINTENANCE COST/YR (MC)	$0	$250	$500	N/A	$500	$1,500	$3,000	$3,000
SPARE PARTS (SP)	$0	$0	$2,850	N/A	$4,500	$5,850	$14,550	$13,290
TRAINING COSTS (TC)	$0	$0	$1,500	N/A	$1,500	$4,000	$15,000	$6,000
SERVICE LIFE YRS (SL)	20	20	20	N/A	20	20	20	20
MTBF	---	---	22,000	N/A	50,000	100,000	60,000	100,000
LIFE-CYCLE COSTS	$50	$6,116	$8,124	N/A	$10,640	$13,283	$23,603	$20,562

LIFE-CYCLE COSTS EQUALS ((EC+IC+SP+TC)/SL)+OC+MC $ PER YEAR

ENERGY COSTS - $0.1/kWh

IF DEVICE IS LOCATED IN HVAC AREA MULTIPLY OPERATING COST FACTOR BY 1.33%

TABLE 5. POWER PROBLEM CORRECTIVE MATRIX
SIMPLE COST COMPARISON CHART
THREE-PHASE

100,000 VA EQUIPMENT SIZE

	SURGE (SPIKE) SUPPRESSOR	ULTRA-ISOLATOR	REGULATOR (W/ISOLATION)	CONSTANT VOLTAGE TRANSFORMER	MAGNETIC SYNTHESIZER	MOTOR GENERATOR	STATIC UPS	ROTARY UPS
EQUIPMENT COST(EC)	$500	$14,000	$22,000	N/A	$35,000	$45,000	$106,000	$103,600
INSTALLATION COST (IC)	$500	$50,000	$50,000	N/A	$50,000	$70,000	$100,000	$100,000
OPERATING COSTS/YR (OC)	$0	$3,688	$5,275	N/A	$7,787	$7,787	$12,367	$9,556
MAINTENANCE COST/YR (MC)	$0	$250	$500	N/A	$500	$1,500	$3,000	$3,000
SPARE PARTS (SP)	$0	$0	$3,300	N/A	$5,250	$6,750	$15,900	$15,540
TRAINING COSTS (TC)	$0	$0	$1,500	N/A	$1,500	$4,000	$15,000	$6,000
SERVICE LIFE YRS (SL)	20	20	20	N/A	20	20	20	20
MTBF	---	---	22,000	N/A	50,000	100,000	60,000	100,000
LIFE-CYCLE COSTS	$50	$7,138	$9,615	N/A	$12,874	$15,574	$27,212	$23,813

LIFE-CYCLE COSTS EQUALS ((EC+IC+SP+TC)/SL)+OC+MC $ PER YEAR

ENERGY COSTS - $0.1/kWh

IF DEVICE IS LOCATED IN HVAC AREA MULTIPLY OPERATING COST FACTOR BY 1.33%

TABLE 6. POWER PROBLEM CORRECTIVE MATRIX
SIMPLE COST COMPARISON CHART
THREE-PHASE

125,000 VA EQUIPMENT SIZE

	SURGE (SPIKE) SUPPRESSOR	ULTRA-ISOLATOR	REGULATOR (W/ISOLATION)	CONSTANT VOLTAGE TRANSFORMER	MAGNETIC SYNTHESIZER	MOTOR GENERATOR	STATIC UPS	ROTARY UPS
EQUIPMENT COST(EC)	$500	$15,000	N/A	N/A	$39,000	$48,600	$115,000	$113,600
INSTALLATION COST (IC)	$500	$50,000	N/A	N/A	$50,000	$70,000	$100,000	$100,000
OPERATING COSTS/YR (OC)	$0	$4,611	N/A	N/A	$9,733	$9,733	$15,459	$11,945
MAINTENANCE COST/YR (MC)	$0	$250	N/A	N/A	$500	$1,500	$3,000	$3,000
SPARE PARTS (SP)	$0	$0	N/A	N/A	$5,850	$7,290	$17,250	$17,040
TRAINING COSTS (TC)	$0	$0	N/A	N/A	$1,500	$4,000	$15,000	$6,000
SERVICE LIFE YRS (SL)	20	20	N/A	N/A	20	20	20	20
MTBF	---	---	N/A	N/A	50,000	100,000	60,000	100,000
LIFE-CYCLE COSTS	$50	$8,111	N/A	N/A	$15,051	$17,728	$30,821	$26,777

LIFE-CYCLE COSTS EQUALS ((EC+IC+SP+TC)/SL)+OC+MC $ PER YEAR

ENERGY COSTS - $0.1/kWh

IF DEVICE IS LOCATED IN HVAC AREA MULTIPLY OPERATING COST FACTOR BY 1.33%

Figure 1.

COST COMPARISON CHART

EQUIPMENT COSTS

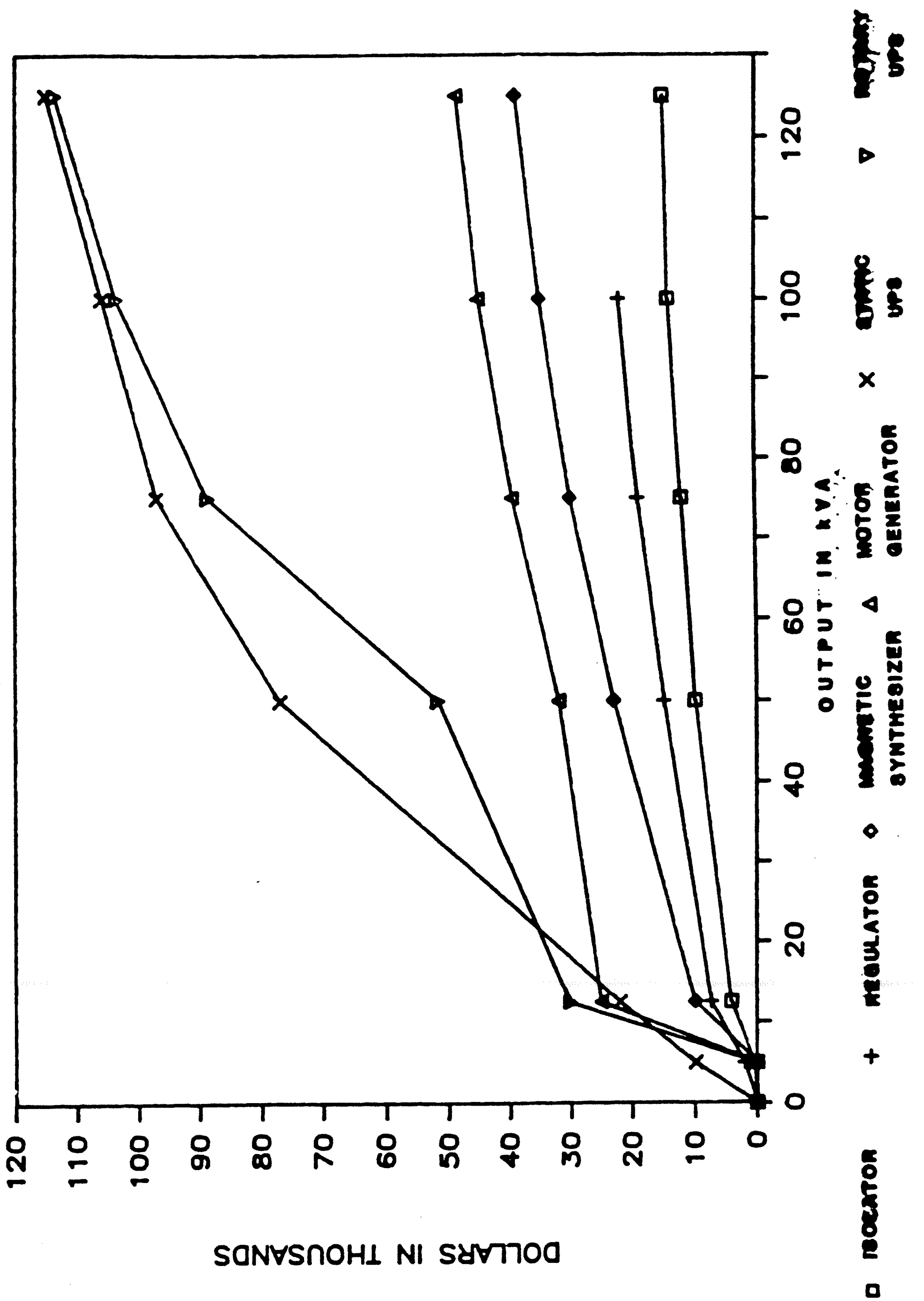

Figure 2.

ANNUAL COST COMPARISON CHART

ESTIMATED ENERGY COSTS

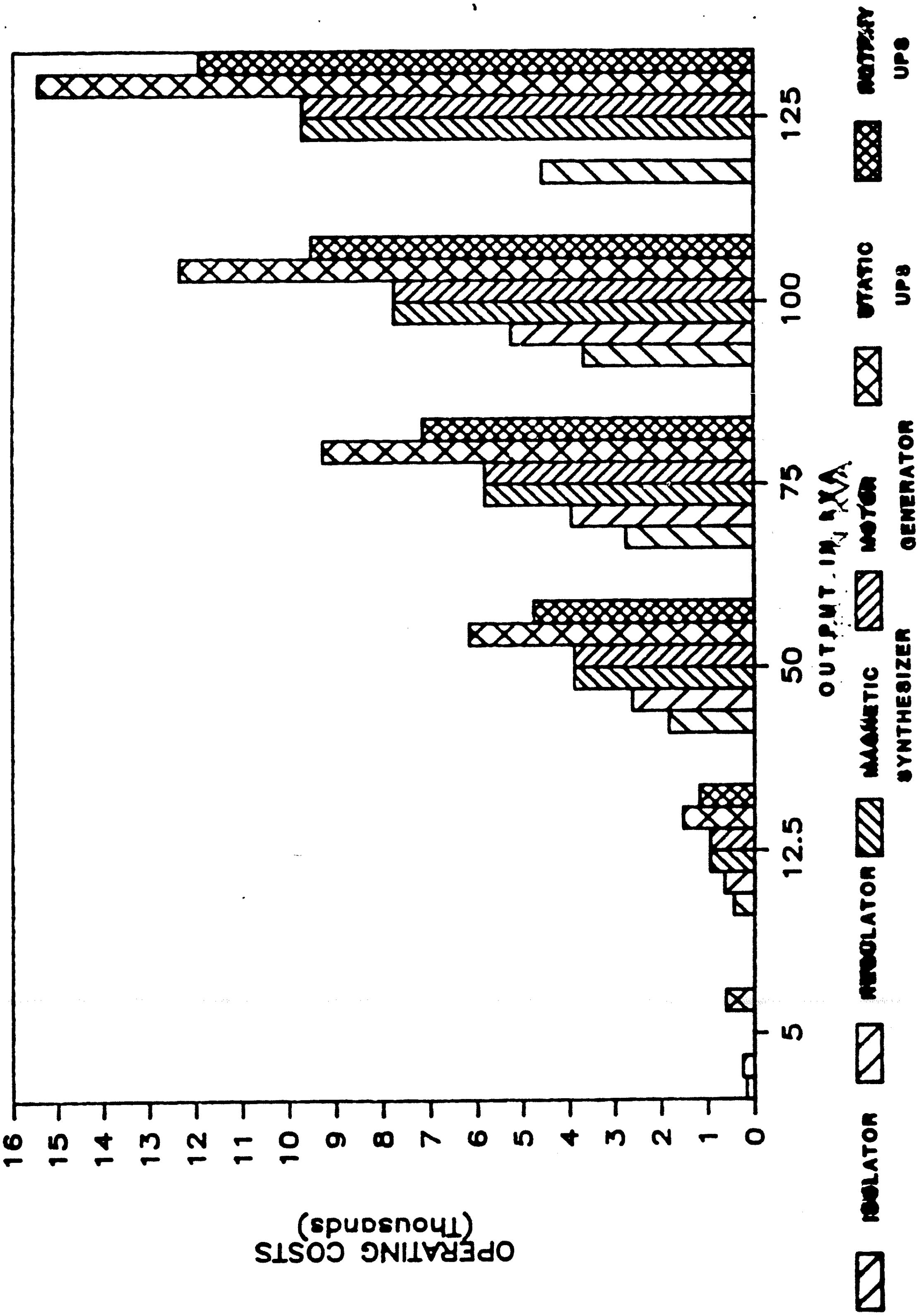

Figure 3.

ANNUAL MAINTENANCE COMPARISON CHART

PREVENTIVE MAINTENANCE ONLY